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SYNCHRONOUS COMPENSATOR PLANT

Technical field:

The present invention relates to electric machines intended for connection to distribution or transmission networks, hereinafter termed power networks. More specifically the invention relates to synchronous compensator plants for the above purpose, to the use of such a plant and to a method for phase compensation.

Background art:

Reactive power is present in all electric power systems that transfer alternating current. Many loads consume not only active power but also reactive power. Transmission and distribution of electric power per se entails reactive losses as a result of series inductances in transformers, overhead lines and cables. Overhead lines and cables also produce reactive power as a result of capacitive connections between phases and between phases and earth potential.

At stationary operation of an alternating current system, active power production and consumption must be in agreement in order to obtain nominal frequency. An equally strong coupling exists between reactive power balance and voltages in the electric power network. If reactive power consumption and production are not balanced in a suitable manner, the consequence may be unacceptable voltage levels in parts of the electric power network. An excess of reactive power in one area leads to high voltages, whereas a deficiency leads to low voltages.

Contrary to active power balance at a nominal frequency, which is controlled solely with the aid of the active power control of the generator, a suitable reactive power balance is obtained with the aid of both controllable excitation of synchronous generators and of other components spread out in the system. Examples of such (phase compensation) components are shunt reactors, shunt capacitors, synchronous compensators and SVCs (Static Var. Compensators).

The location of these phase compensation components in the electric power network affects not only the voltage in various parts of the electric power network, but also the losses in the electric power network since the transfer of reactive power, like the transfer of active power, gives rise to losses and thus heating. It is consequently desirable to place phase compensation components so

that losses are minimized and the voltage in all parts of the electric power network is acceptable.

The shunt reactor and shunt capacitor are usually permanently connected or connected via a mechanical breaker mechanism to the electric power network. In other words, the reactive power consumed/produced by these components is not continuously controllable. The reactive power produced/consumed by the synchronous compensator and the SVC, on the other hand, is continuously controllable. These two components are consequently used if there is a demand for high-performance voltage control.

The following is a brief description of the technology for phase compensation with the aid of synchronous compensator and SVC.

A synchronous compensator is in principle a synchronous motor running at no load, i.e. it takes active power from the electric power network equivalent to the machine losses.

The rotor shaft of a synchronous compensator is usually horizontal and the rotor generally has six or eight salient poles. The rotor is usually dimensioned thermally so that the synchronous compensator, in over-excited state, can produce approximately 100 % of the apparent power the stator is thermally dimensioned for (rated output) in the form of reactive power. In under-excited state, when the synchronous compensator consumes reactive power, it consumes approximately 60 % of the rated output (standard value, depending on how the machine is dimensioned). This gives a control area of approximately 160 % of rated output over which the reactive power consumption/production can be continuously controlled. If the machine has salient poles with relatively little reactance in transverse direction, and is provided with excitation equipment enabling both positive and negative excitation, more reactive power can be consumed than the 60 % of rated output stated above, without the machine exceeding the stability limit. Modern synchronous compensators are normally equipped with fast excitation systems, preferably a thyristor-controlled static exciter where the direct current is supplied to the rotor via slip rings. This solution enables both positive and negative supply as above.

The magnetic circuits in a synchronous compensator usually comprise a laminated core, e.g. of sheet steel with a welded construction. To provide ventilation and cooling the core is often divided into stacks with radial and/or axial ventilation ducts. For larger machines the laminations are punched out in segments which are attached to the frame of the machine, the laminated core being held

together by pressure fingers and pressure rings. The winding of the magnetic circuit is disposed in slots in the core, the slots generally having a cross section in the shape of a rectangle or trapezium.

In multi-phase electric machines the windings are made as either single or double layer windings. With single layer windings there is only one coil side per slot, whereas with double layer windings there are two coil sides per slot. By coil side is meant one or more conductors combined vertically or horizontally and provided with a common coil insulation, i.e. an insulation designed to withstand the rated voltage of the machine to earth.

Double-layer windings are generally made as diamond windings whereas single layer windings in the present context can be made as diamond or flat windings. Only one (possibly two) coil width exists in diamond windings whereas flat windings are made as concentric windings, i.e. with widely varying coil width. By coil width is meant the distance in arc dimension between two coil sides pertaining to the same coil.

Normally all large machines are made with double-layer winding and coils of the same size. Each coil is placed with one side in one layer and the other side in the other layer. This means that all coils cross each other in the coil end. If there are more than two layers these crossings complicate the winding work and the coil end is less satisfactory.

It is considered that coils for rotating machines can be manufactured with good results up to a voltage range of 10 - 20 kV.

A synchronous compensator has considerable short-duration overload capacity. In situations when electro-mechanical oscillations occur in the power system the synchronous compensator can briefly supply reactive power up to twice the rated output. The synchronous compensator also has a more long-lasting overload capacity and is often able to supply 10 to 20 % more than rated output for up to 30 minutes.

Synchronous compensators exist in sizes from a few MVA to hundreds of MVA. The losses for a synchronous compensator cooled by hydrogen gas amount to approximately 10 W/kvar, whereas the corresponding figure for air-cooled synchronous compensators is approximately 20 W/kvar.

Synchronous compensators were preferably installed in the receiving end of long radial transmission lines and in important nodes in masked electric power networks with long transmission lines,

particularly in areas with little local generation. The synchronous compensator is also used to increase the short-circuit power in the vicinity of HVDC inverter stations.

The synchronous compensator is most often connected to points in the electric power network where the voltage is substantially higher than the synchronous compensator is designed for. This means that, besides the synchronous compensator, the synchronous compensator plant generally includes a step-up transformer, a busbar system between synchronous compensator and transformer, a generator breaker between synchronous compensator and transformer, and a line breaker between transformer and electric power network, see the single-line diagram in Figure 1.

In recent years SVCs have to a great extent replaced synchronous compensators in new installations because of their advantages particularly with regard to cost, but also in certain applications because of technical advantages.

The SVC concept (Static Var. Compensator) is today the leading concept for reactive power compensation and, as well as in many cases replacing the synchronous compensator in the transmission network, it also has industrial applications in connection with electric arc furnaces. SVCs are static in the sense that, contrary to synchronous compensators, they have no movable or rotating main components.

SVC technology is based on rapid breakers built up of semi-conductors, thyristors. A thyristor can switch from isolator to conductor in a few millionths of a second. Capacitors and reactors can be connected or disconnected with negligible delay with the aid of thyristor bridges. By combining these two components reactive power can be steplessly either supplied or extracted. Capacitor banks with different reactive power enable the supplied reactive power to be controlled in steps.

A SVC plant consists of both capacitor banks and reactors and since the thyristors generate harmonics, the plant also includes harmonic filters. Besides control equipment, a transformer is also required between the compensation equipment and the network in order to obtain optimal compensation from the size and cost point of view. SVC plant is available in size from a few MVA up to 650 MVA, with nominal voltages up to 765 kV.

Various SVC plant types exist, named after how the capacitors and reactors are combined. Two usual elements that may be included are TSC or TCR. TSC is a thyristor-controlled reactive power-producing

capacitor and TCR is a thyristor-controlled reactive power-consuming reactor. A usual type is a combination of these elements, TSC/TCR.

The magnitude of the losses depends much on which type of plant the SVC belongs to, e.g. a FC/TCR type (FC means that the capacitor is fixed) has considerably greater losses than a TSC/TCR. The losses for the latter type are approximately comparable with the losses for a synchronous compensator.

It should be evident from the above summary of the phase compensation technology that this can be divided into two principal concepts, namely synchronous compensation and SVC.

These concepts have different strengths and weaknesses. Compared with the synchronous compensator, the SVC has the main advantage of being cheaper. However, it also permits somewhat faster control which may be an advantage in certain applications.

The drawbacks of the SVC as compared with the synchronous compensator include:

- it has no overload capacity. In operation at its capacitive limit the SVC becomes in principle a capacitor, i.e. if the voltage drops then the reactive power production drops with the square of the voltage. If the purpose of the phase compensation is to enable transfer of power over long distances the lack of overload capacity means that, in order to avoid stability problems, a higher rated output must be chosen if SVC plant is selected than if synchronous compensator plant is selected.

- it requires filters if it includes a TCR.

- it does not have a rotating mass with internal voltage source. This is an advantage with the synchronous compensator, particularly in the vicinity of HVDC transmission.

In order to achieve a more competitive electricity market many countries have deregulated, or are in the process of deregulating, the electricity market. This usually involves a separation of power production and transmission services into separate entities. When these two parts of the system are in different hands, the previously existing link between the planning of generation plants and transmission lines is broken. A generation plant owner may announce the closing of a generation plant at timescales which are, for hardware investments, very short, presenting the operators and planners of transmission services with major changes in both load flow patterns and the location of controllable reactive

production/consumption resources at short notice. Consequently, there is a strategic need for a phase compensation unit that can be relocated, within short lead time, to an arbitrary node in the transmission system.

In countries where the electricity market has not been deregulated there may also exist a need to have relocatable phase compensation components. For instance, countries with a large share of nuclear power production may encounter situations similar to that described above. Normally, nuclear power plants are closed down once a year, during a low load season, for inspections and reparations. However, occasionally these plants may have to stay closed for longer periods of time due to major reparations. Although this situation is easier to handle in a country which has not deregulated the electricity market, the size of a typical nuclear plant may imply that the changes in load flow patterns and the absence of controllable reactive production/consumption resources puts the operators of the transmission system in situations which are difficult to handle while maintaining prescribed security standards. There exists a need for a relocatable phase compensation unit also in these situations.

There exist today a small number of relocatable SVC plants, see e.g. the article "Relocatable static var compensators help control unbundled power flows" in the Magazine "Modern Power Systems", December 1996, pages 49-54. In addition to the differences between a static and a synchronous compensator described above, the relocatable static compensator involves a number of containers, which requires a fairly large area at the site and which needs to be electrically interconnected at the site. But most importantly the relocatable static compensator can only be connected to nodes in the transmission system where a step-down transformer already is available, providing a fairly low voltage. In other words, the relocatable static compensator cannot be directly connected to the transmission system voltage (typically 130 kV and up).

Due to the number of components required in a synchronous compensator plant and in particular the up to now necessary presence of a transformer, synchronous compensator plants for high-voltage networks up to now have been realized solely as stationary plants. In case of change in an existing power network regarding the need for phase compensation the plant might be superfluous at its location or might be required to be designed and dimensioned different, or a plant might be required somewhere else in the

network. This of course is a serious drawback with such a stationary plant.

Description of the invention:

The object of the present invention is to attain a synchronous compensator plant avoiding this drawback.

According to the invention this object has been achieved in that a synchronous compensator plant of the kind specified in the preamble of claim 1 includes the specific features specified in the characterizing portion of the claim.

Thanks to the fact that the winding(s) in the rotating electric machine in the synchronous compensator plant is/are manufactured with this special solid insulation, a voltage level can be achieved for the machine which is far above the limits a conventional machine of this type can be practically or financially constructed for. The voltage level may reach any level applicable in power networks for distribution and transmission. The advantage is thus achieved that the synchronous compensator can be connected directly to such networks without intermediate connection of a step-up transformer.

Elimination of the transformer per se entails great savings in cost, weight and space, but also has other decisive advantages over a conventional synchronous compensator plant.

The efficiency of the plant is increased and the losses are avoided that are incurred by the transformer's consumption of reactive power and the resultant turning of the phase angle. This has a positive effect as regards the static and dynamic stability margins of the system. Furthermore, a convention transformer contains oil, which entails a fire risk. This is eliminated in a plant according to the invention, and the requirement for various types of fire-precautions is reduced. Many other electrical coupling components and protective equipment are also reduced. This gives reduced plant costs and less need for service and maintenance.

These and other advantages result in a synchronous compensator plant being considerably smaller and less expensive than a conventional plant, and that the operating economy is radically improved thanks to less maintenance and smaller losses.

Thanks to these advantages a synchronous compensator plant according to the invention will contribute to this concept being financially competitive with the SVC concept (see above) and even offering cost benefits in comparison with this.

The fact that the invention makes the synchronous compensator concept competitive in comparison with the SVC concept therefore enables a return to the use of synchronous compensator plants. The drawbacks associated with SVC compensation are thus no longer relevant. The complicated, bulky banks of capacitors and reactors in a SVC plant are one such drawback. Another big drawback with SVC technology is its static compensation which does not give the same stability as that obtained by the inertia obtained in a rotating electric machine with its rotating e.m.f. as regards both voltage and phase angle. A synchronous compensator is therefore better able to adjust to temporary interference in the network and to fluctuations in the phase angle. The thyristors that control a SVC plant are also sensitive to displacement of the phase angle. A plant according to the invention also enables the problem of harmonics to be solved.

The synchronous compensator plant according to the invention thus enables the advantages of synchronous compensator technology over SVC technology to be exploited so that a more efficient and stable compensation is obtained at a cost superior to this from the point of view of both plant investment and operation.

The plant according to the invention is small, inexpensive, efficient and reliable, both in comparison with a conventional synchronous compensator and a SVC.

The reduction of the amount of required components in the plant and in particular the elimination of the transformers in the plant makes the design of the plant as a mobile unit possible, which thus is included as an essential feature of claim 1. By making the plant as a mobile unit that can be transported by a lorry, a railway truck, a helicopter or the like, the plant can be moved from one location of a power network to another, should the need for phase compensation in the network change.

With a synchronous compensator plant having components with windings of the specific construction as claimed in claim 1 and making use of the possibility to design the plant as a mobile unit the drawbacks related to stationary synchronous compensator plants thus are overcome. This is primarily of relevance for high-voltage networks, in particular in the range of 36 kV and above.

Another object of the invention is to satisfy the need for fast, continuously controllable reactive power which is directly connected to sub-transmission or transmission level in order to manage the system stability and/or dependence on rotating mass and

the electro-motive force in the vicinity of HVDC transmission. The plants shall be able to supply anything from a few MVA up to several hundreds of MVA.

The advantage gained by satisfying said objects is the avoidance of the intermediate transformer, the reactance of which otherwise consumes reactive power. This also enables the avoidance of traditional high-power breakers. Advantages are also obtained as regards network quality since there is rotating compensation. With a plant according to the invention the overload capacity is also increased, which with the invention may be +100 %. The synchronous compensator according to the invention may be given higher overload capacity in over-excited operation than conventional synchronous compensators, both as regards short-during and long-duration overload capacity. This is primarily because the time constants for heating the stator are large with electric insulation of the stator winding according to the invention. However, the thermal dimensioning of the rotor must be such that it does not limit the possibilities of exploiting this overload capacity.

To accomplish this the magnetic circuit in the electric machine included in the synchronous compensator plant is formed with threaded permanent insulating cable with included earth. The invention also relates to a procedure for manufacturing such a magnetic circuit.

The major and essential difference between known technology and the embodiment according to the invention is thus that this is achieved with an electric machine provided with solid insulation, the magnetic circuit(s) of the winding(s) being arranged to be directly connected via breakers and isolators to a high supply voltage of between 20 and 800 kV, preferably higher than 36 kV. The magnetic circuit thus comprises a laminated core having a winding consisting of a threaded cable with one or more permanently insulated conductors having a semiconducting layer both at the conductor and outside the insulation, the outer semiconducting layer being connected to earth potential.

To solve the problems arising with direct connection of electric machines to all types of high-voltage power networks, a machine in the plant according to the invention has a number of features as mentioned above, which differ distinctly from known technology. Additional features and further embodiments are defined in the dependent claims and are discussed in the following.

Such features mentioned above and other essential characteristics of the synchronous compensator plant and the electric machine according to the invention included therein, include the following:

- The winding of the magnetic circuit is produced from a cable having one or more permanently insulated conductors with a semiconducting layer at both conductor and sheath. Some typical conductors of this type are PEX cable or a cable with EP rubber insulation which, however, for the present purpose are further developed both as regards the strands in the conductor and the nature of the outer sheath. PEX = crosslinked polyethylene (XLPE). EP = ethylene propylene.

- Cables with circular cross section are preferred, but cables with some other cross section may be used in order to obtain better packing density, for instance.

- Such a cable allows the laminated core to be designed according to the invention in a new and optimal way as regards slots and teeth.

- The winding is preferably manufactured with insulation in steps for best utilization of the laminated core.

- The winding is preferably manufactured as a multi-layered, concentric cable winding, thus enabling the number of coil-end intersections to be reduced.

- The slot design is suited to the cross section of the winding cable so that the slots are in the form of a number of cylindrical openings running axially and/or radially outside each other and having an open waist running between the layers of the stator winding.

- The design of the slots is adjusted to the relevant cable cross section and to the stepped insulation of the winding. The stepped insulation allows the magnetic core to have substantially constant tooth width, irrespective of the radial extension.

- The above-mentioned further development as regards the strands entails the winding conductors consisting of a number of impacted strata/layers, i.e. insulated strands that from the point of view of an electric machine, are not necessarily correctly transposed, uninsulated and/or insulated from each other.

- The above-mentioned further development as regards the outer sheath entails that at suitable points along the length of the conductor, the outer sheath is cut off, each cut partial length being connected directly to earth potential.

The use of a cable of the type described above allows the entire length of the outer sheath of the winding, as well as other parts of the plant, to be kept at earth potential. An important advantage is that the electric field is close to zero within the coil-end region outside the outer semiconducting layer. With earth potential on the outer sheath the electric field need not be controlled. This means that no field concentrations will occur either in the core, in the coil-end regions or in the transition between them.

The mixture of insulated and/or uninsulated impacted strands, or transposed strands, results in low stray losses.

The cable for high voltage used in the magnetic circuit winding is constructed of an inner core/conductor with a plurality of strands, at least two semiconducting layers, the innermost being surrounded by an insulating layer, which is in turn surrounded by an outer semiconducting layer having an outer diameter in the order of 20-250 mm and a conductor area in the order of 30-3000 mm^2.

According to a particularly preferred embodiment of the invention, at least two of these layers, preferably all three, have the same coefficient of thermal expansion. The decisive benefit is thus achieved that defects, cracks or the like are avoided at thermal movement in the winding.

The invention also relates to a procedure for manufacturing the magnetic circuit for the electric machine included in the synchronous compensator plant. The procedure entails the winding being placed in the slots by threading the cable through the cylindrical openings in the slots.

From another aspect of the invention, the object has been achieved in that a plant of the type described in the preamble to claim 35 is given the special features defined in the characterizing part of this claim.

Since the insulation system, suitably permanent, is designed so that from the thermal and electrical point of view it is dimensioned for over 36 kV, the plant can be connected to high-voltage power networks without any intermediate step-up transformer, thereby achieving the advantages referred to above. Such a plant is preferably, but not necessarily, constructed to include the features defined for the plant as claimed in any of claims 1-34.

The above-mentioned and other advantageous embodiments of the invention are defined in the dependent claims.

Brief description of the drawings:

The invention will be described in more detail in the following detailed description of a preferred embodiment of the construction of the magnetic circuit of the electrical machine in the synchronous compensator plant, with reference to the accompanying drawings in which

Figure 1 shows a single line diagram of the invented synchronous compensator plant.

Figure 2 shows a schematic axial end view of a sector of the stator in an electric machine in the synchronous compensator plant according to the invention, and

Figure 3 shows an end view, step-stripped, of a cable used in the winding of the stator according to Figure 2

Figure 4 schematically shows the invented plant transported on a lorry

Description of a preferred embodiment:

Figure 1 shows a single line diagram of the synchronous compensator plant according to a preferred embodiment of the invention, where the machine is arranged for direct connection to the power network, without any step-up transformer, at two different voltage levels.

In the schematic axial view through a sector of the stator 1 according to Figure 2, pertaining to the electric machine included in the synchronous compensator plant, the rotor 17 of the machine is also indicated. The stator 1 is composed in conventional manner of a laminated core. Figure 2 shows a sector of the machine corresponding to one pole pitch. From a yoke part 9 of the core situated radially outermost, a number of teeth 4 extend radially in towards the rotor 17 and are separated by slots 7 in which the stator winding is arranged. Cables 6 forming this stator winding, are high-voltage cables which may be of substantially the same type as those used for power distribution, i.e. PEX cables, but without any outer, mechanically-protective sheath. Thus, the semiconducting layer which is sensitive to mechanical damage lies naked on the surface of the cable.

The cables 6 are illustrated schematically in Figure 2, only the conducting central part of each cable part or coil side being drawn in. As can be seen, each slot 7 has varying cross section with alternating wide parts and narrow parts. The wide parts are substantially circular and surround the cabling, the waist parts

between these forming narrow parts. The waist parts serve to radially fix the position of each cable. The cross section of the slot 7 also narrows radially inwards. This is because the voltage on the cable parts is lower the closer to the radially inner part of the stator 1 they are situated. Slimmer cabling can therefore be used there, whereas coarser cabling is necessary further out. In the example illustrated, cables of three different dimensions are used, arranged in three correspondingly dimensioned sections of slots 7.

Figure 3 is showing a cross section through a high voltage winding 6 used in the present invention. The high voltage winding 6 comprises a current-carrying conductor in the form of a number of strands 12 with circular cross sections which strands 12 are arranged in the middle of the high voltage winding 6. Around the strands 12 there is a first layer 13 with semiconducting properties. Around the first semiconducting layer 13 is arranged a layer of solid isolation 14 for example PEX-isolation. Around the isolation layer 14 there is a second layer 15 with semiconducting properties. The diameter of the high voltage winding is 20 - 250 mm and the conducting area lies in the interval of 80 - 3000 mm^2.

In figure 4 it is schematically illustrated how the complete plant constitutes a mobile unit 21 that can be transported on a lorry.

CLAIMS

1. A synchronous compensator plant comprising at least one rotating electric machine having at least one winding, characterized in that the winding in at least one of the electric machines comprises an insulation system including at least two semiconducting layers, each layer constituting essentially an equipotential surface and also including solid insulation disposed therebetween, and in that the plant is a mobile unit in the sense that with regard to size and weight and number of components substantially the complete unit (21) is transportable by a lorry, a railway truck, or a helicopter.

2. A plant as claimed in claim 1, characterized in that at least one of the layers has substantially the same coefficient of thermal expansion as the solid insulation.

3. A plant as claimed in either of claims 1 or 2, characterized in that the insulation is built up of a cable (6) intended for high voltage and comprising one or more current-carrying conductors (31) surrounded by at least one semiconducting layer (32, 34) with intermediate insulating layer (33) of solid insulation.

4. A plant as claimed in claim 3, characterized in that the innermost semiconducting layer (32) is at substantially the same potential as the conductor(s) (31).

5. A plant as claimed in either of claims 3 or 4, characterized in that the one of the outer semiconducting layers (34) is arranged to form essentially an equipotential surface surrounding the conductor(s) (31).

6. A plant as claimed in claim 5, characterized in that said outer semiconducting layer (34) is connected to a selected potential.

7. A plant as claimed in claim 6, characterized in that the selected potential is earth potential.

8. A plant as claimed in any of claims 3-7, characterized in that at least two of said layers have substantially the same coefficient of thermal expansion.

9. A plant as claimed in any of claims 3-5, characterized in that the current carrying conductor comprises a plurality of strands, only a few of the strands being uninsulated from each other.

10. A plant as claimed in any of claims 1-9, characterized in that the winding consists of a cable comprising one or more current-carrying conductors (2), each conductor consisting of a number of strands, an inner semiconducting layer (3) being arranged around each conductor, an insulating layer (4) of solid insulation being arranged around each inner semiconducting layer (3) and an outer semiconducting layer (5) being arranged around each insulating layer (4).

11. A plant as claimed in claim 10, characterized in that the cable also comprises a metal screen and a sheath.

12. A plant as claimed in any of the preceding claims, characterized in that the magnetic circuit is arranged in a rotating electric machine, the stator (3) of which is cooled at earth potential.

13. A plant as claimed in any of the preceding claims, characterized in that the magnetic circuit of the electric machine comprises a stator winding placed in a slot (5), said slot (5) being designed as a number of cylindrical openings (7) running axially and radially outside each other, having substantially circular cross section and separated by narrow waist parts (8) between the cylindrical openings.

14. A plant as claimed in claim 13, characterized in that the phases of the stator winding are Y-connected.

15. A plant as claimed in claim 14, characterized in that the Y-point of the stator winding is insulated from earth potential or connected to earth potential via a high-ohmic impedance and protected from over-voltages by means of surge arresters.

16. A plant as claimed in claim 14, characterized in that the Y-point of the stator winding is earthed via a suppression filter of third harmonic type, which suppression filter is designed to greatly reduce or eliminate third harmonic currents in the electric machine at the same time as being dimensioned to limit voltages and currents in the event of faults in the plant.

17. A plant as claimed in claim 16, characterized in that the suppression filter is protected from over-voltages by means of surge arresters, the latter being connected in parallel with the suppression filter.

18. A plant as claimed in claims 3 and 14, characterized in that the cable (6) constituting the stator winding has a

gradually decreasing insulation seen from the high-voltage side towards the Y-point.

19. A plant as claimed in claim 18, characterized in that the gradual decrease in the insulation thickness is stepwise or continuous.

20. A plant as claimed in claims 13 and 18, characterized in that the circular cross section (7) of the substantially cylindrical slots (5) for the stator winding has decreasing radius seen from the yoke portion towards the rotor.

21. A plant as claimed in any of claims 12-20, characterized in that the rotating part has an inertia and electromotive force.

22. A plant as claimed in claim 21, characterized in that the machine can be started from a local power supply.

23. A plant as claimed in claim 22, characterized in that the machine has two or more poles.

24. A plant as claimed in claim 23, characterized in that the rotor (2) and the stator (3) are so dimensioned that at nominal voltage, nominal power factor and over-excited operation, the thermally based current limits of stator and rotor are exceeded approximately simultaneously.

25. A plant as claimed in claim 23, characterized in that the rotor (2) and the stator (3) are so dimensioned that at nominal voltage, nominal power factor and over-excited operation, the thermally based stator current limit is exceeded before the thermally based rotor current limit has been exceeded.

26. A plant as claimed in either of claims 24 or 25, characterized in that is has 100% overload capacity at nominal voltage, nominal power factor and at over-excited operation.

27. A plant as claimed in claim 24 or claim 25, characterized in that the rotor poles are pronounced.

28. A plant as claimed claim 27, characterized in that the quadrature-axis synchronous reactance is considerably less than the direct-axis synchronous reactance.

29. A plant as claimed claim 28, characterized in that the machine is equipped with excitation systems enabling both positive and negative excitation.

30. A plant as claimed in any of claims 3-29, characterized in that the cables (6) with solid insulation intended for high voltage have a conductor area between 30 and 3000 mm^2 and have an outer cable diameter of between 20 and 250 mm.

31. A plant as claimed in any of the preceding claims, characterized in that the stator and rotor circuits (3, 2) are provided with cooling means in which the coolant is in liquid and/or gaseous form.

32. A plant as claimed in any of the preceding claims, characterized in that the machine is arranged for connection to several different voltage levels.

33. A plant as claimed in any of claims 1-32, characterized in that the machine is connected to the power network without any step-up transformer.

34. A plant as claimed in any of the preceding claims, characterized in that the winding of the machine is arranged for self-regulating field control and lacks auxiliary means for control of the field.

35. A plant as claimed in any of the preceding claims, characterized in that the winding has an insulation system which, as regards its thermal and electrical properties, permits a voltage level in the machine exceeding 36 kV.

36. A plant as claimed in any of the preceding claims, characterized in that the plant is mounted on wheels.

37. The use of a plant according to any of claims 1-36 for phase compensation at different localities of a high voltage power network.

38. A method for phase compensation in a high voltage power network characterized in that a plant according to any of claims 1-36 is transported between different localities in the network for phase compensation at these different localities.

ABSTRACT

The magnetic circuit of synchronous compensator plant is included in an electric machine which is directly connected to a high supply voltage of 20 - 800 kV, preferably higher than 36 kV. The electric machine is provided with solid insulation and its winding(s) is/are built up of a cable (6) intended for high voltage comprising one or more current-carrying conductors (31) with a number of strands (36) surrounded by at least one outer and one inner semiconducting layer (34, 32) and intermediate insulating layers (33). The plant is made as a mobile unit.

(Figure 2.)

Denna sida utgör en del av ansökningstexten och innehåller såväl beskrivningstext som patentkrav. Vi avser att senare inkomma med ny version av ansökningstexten med innehållet på denna sida inredigerad.

Den isolerade ledaren eller högspänningskabeln som används vid föreliggande uppfinning är flexibel och böjlig och av det slag som närmare beskrivs i PCT ansökan SE97/00874 och SE97/00875. Ytterligare beskrivning av den isolerade ledaren eller kabeln finns i PCT ansökningarna SE97/00901, SE97/00902 och SE97/00903.

En kabel avsedd att kunna användas i en elektrisk maskin där kabeln består av en ledande kärna omgiven av två halvledande skikt och mellanliggande fast isolering är förut känd genom US 5036165. Den kända kabeln är dock icke avsedd att användas för höga spänningar och är av flera skäl omöjlig eller olämplig att tillämpa vid föreliggande uppfinning. Framför allt beror det på att den kända kabeln är av stel typ, dvs de kärnan omgivande skikten är armerade på ett sådant sätt att kaben inte går att böja . Skulle man försöka göra det kommer bristningar att uppstå mellan skikten liksom i de fall då kabeln utsätter för termisk expansion.

Enligt en föredragen utföringsform av uppfinningen är den isolerade ledaren eller kabeln som används i anordningen flexibel. De olika skikten i kabeln vidhäftar varandra även då kabeln böjs.

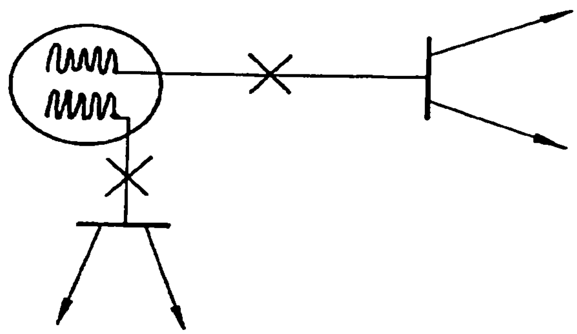
I figuren som visar den detalj av uppfinningen som avser den isolerade ledaren eller kabeln är de tre skikten utförda så att de vidhäftar varandra även då kabeln böjes. Den visade kabeln är flexibel och denna egenskap bibehålles vid kabeln under dess livslängd.

Patentkrav

101. Anordning enligt något av föregående patentkrav, kännetecknad av att den isolerade ledaren eller högspänningskabeln är flexibel.

102. Anordning enligt patentkravet 101, kännetecknad av att skikten är anordnade att vidhäfta varandra även då den isolerade ledaren eller kabeln böjes.

Fig. 1



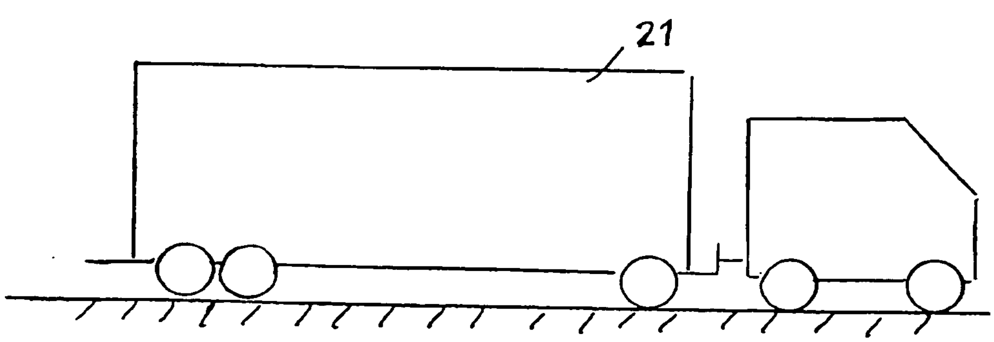


Fig. 4

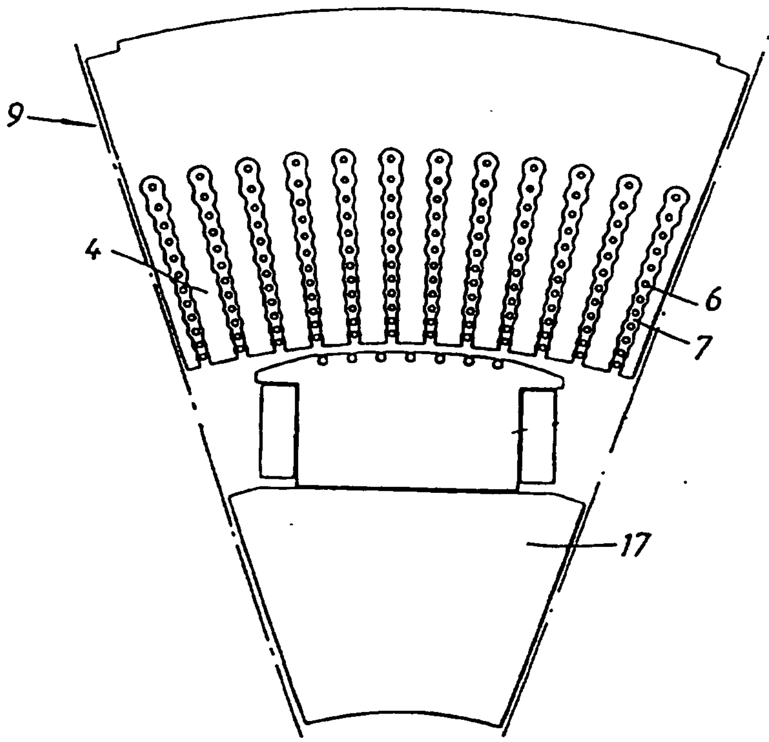


Fig. 2

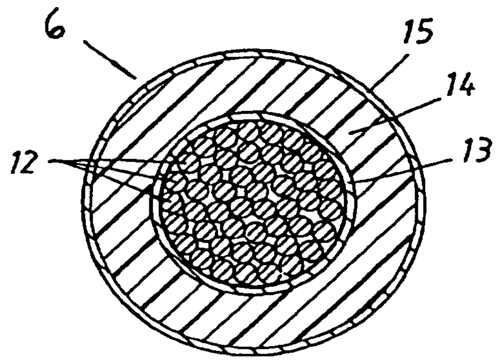


Fig. 3